

CONTENTS

Section		Page
1	INTRODUCTION	1-1
1.1	Hubble Space Telescope Configuration	1-3
1.1.1	Optical Telescope Assembly	1-4
1.1.2	The Science Instruments	1-5
1.1.3	Support Systems Module	1-7
1.1.4	Solar Arrays	1-7
1.1.5	Computers	1-7
1.2	The Hubble Space Telescope Program	1-7
1.3	The Value of Servicing	1-9
2	HUBBLE SPACE TELESCOPE SERVICING MISSION 3A	2-1
2.1	Reasons for Orbital Servicing	2-1
2.2	Orbital Replacement Units	2-2
2.3	Shuttle Support Equipment	2-3
2.3.1	Remote Manipulator System	2-4
2.3.2	Space Support Equipment	2-4
2.3.3	Orbital Replacement Unit Carrier	2-5
2.4	Astronaut Roles and Training	2-7
2.5	Extravehicular Crew Aids and Tools	2-9
2.6	Astronauts of the Servicing Mission 3A	2-9
2.7	Servicing Mission Activities	2-12
2.7.1	Rendezvous With the Hubble Space Telescope	2-12
2.7.2	Extravehicular Servicing Activities – Day by Day	2-13
2.8	Future Servicing Plans	2-26
3	HUBBLE SPACE TELESCOPE SCIENCE AND DISCOVERIES	3-1
3.1	Planets	3-1
3.2	Formation and Evolution of Stars and Planets	3-6
3.3	Galaxies and Cosmology	3-10
3.4	Summary	3-15
4	SCIENCE INSTRUMENTS	4-1
4.1	Space Telescope Imaging Spectrograph	4-1
4.1.1	Physical Description	4-1
4.1.2	Spectra Operational Modes	4-7
4.1.3	STIS Specifications	4-8
4.1.4	Observations	4-8
4.2	Wide Field and Planetary Camera 2	4-9
4.2.1	Physical Description	4-10
4.2.2	WFPC2 Specifications	4-13
4.2.3	Observations	4-13
4.3	Astrometry (Fine Guidance Sensors)	4-14
4.3.1	Fine Guidance Sensor Specifications	4-14
4.3.2	Operational Modes for Astrometry	4-14
4.3.3	Fine Guidance Sensor Filter Wheel	4-15
4.3.4	Astrometric Observations	4-15

Section	Page	
5	HUBBLE SPACE TELESCOPE SYSTEMS	5-1
5.1	Support Systems Module	5-2
5.1.1	Structures and Mechanisms Subsystem	5-2
5.1.2	Instrumentation and Communications Subsystem	5-7
5.1.3	Data Management Subsystem	5-8
5.1.4	Pointing Control Subsystem	5-10
5.1.5	Electrical Power Subsystem	5-14
5.1.6	Thermal Control	5-16
5.1.7	Safing (Contingency) System	5-16
5.2	Optical Telescope Assembly	5-18
5.2.1	Primary Mirror Assembly and Spherical Aberration	5-19
5.2.2	Secondary Mirror Assembly	5-23
5.2.3	Focal Plane Structure Assembly	5-24
5.2.4	OTA Equipment Section	5-24
5.3	Fine Guidance Sensor	5-25
5.3.1	Fine Guidance Sensor Composition and Function	5-25
5.3.2	Articulated Mirror System	5-27
5.4	Solar Array and Jitter Problems	5-27
5.4.1	Configuration	5-27
5.4.2	Solar Array Subsystems	5-28
5.4.3	Solar Array Configuration for Servicing Mission 3A	5-29
5.5	Science Instrument Control and Data Handling Unit	5-29
5.5.1	Components	5-29
5.5.2	Operation	5-30
5.6	Space Support Equipment	5-31
5.6.1	Flight Support System	5-32
5.6.2	Orbital Replacement Unit Carrier	5-33
5.6.3	Crew Aids	5-35
6	HST OPERATIONS	6-1
6.1	Space Telescope Science Institute	6-1
6.1.1	Scientific Goals	6-1
6.1.2	Institute Software	6-1
6.1.3	Selecting Observation Proposals	6-2
6.1.4	Scheduling Selected Observations	6-2
6.1.5	Data Analysis and Storage	6-2
6.2	Space Telescope Operations Control Center	6-3
6.3	Operational Characteristics	6-3
6.3.1	Orbital Characteristics	6-4
6.3.2	Celestial Viewing	6-4
6.3.3	Solar System Object Viewing	6-5
6.3.4	Natural Radiation	6-5
6.3.5	Maneuver Characteristics	6-6
6.3.6	Communication Characteristics	6-6
6.4	Acquisition and Observation	6-7

Section		Page
7	VALUE ADDED: The Benefits of Servicing Hubble	7-1
7.1	Cost-Effective Modular Design	7-1
7.1.1	Processor Improvements	7-1
7.1.2	Data Archiving Rate	7-1
7.1.3	Detector Technology	7-4
7.1.4	Cryogenic Cooler	7-4
7.1.5	Solar Arrays	7-5
7.1.6	Simultaneous Science	7-5
7.2	Accelerated Innovations	7-5
7.2.1	Detecting Breast Cancer Before Black Holes	7-5
7.2.2	Image Processing: Diagnosing Cancer Earlier	7-6

ILLUSTRATIONS

Figure		Page
1-1	The Hubble Space Telescope (HST) – shown in a clean room at Lockheed Martin Missiles & Space in Sunnyvale, California, before shipment to Kennedy Space Center – is equipped with science instruments and engineering subsystems designed as orbital replacement units.	1-2
1-2	Schedule of extravehicular activities	1-3
1-3	HST overall configuration	1-4
1-4	HST exploded view	1-5
1-5	Hubble Space Telescope specifications	1-6
1-6	Organization summary for HST program operational phase	1-8
1-7	HST data collecting network	1-9
2-1	Hubble Space Telescope Servicing Mission 3A Orbital Replacement Units	2-3
2-2	Servicing Mission 3A Payload Bay configuration	2-4
2-3	Flight Support System configuration	2-5
2-4	Orbital Replacement Unit Carrier	2-6
2-5	Neutral Buoyancy Laboratory at NASA Johnson Space Center	2-8
2-6	The STS-103 mission has seven crewmembers. They are (from left) Mission Specialist C. Michael Foale, Mission Specialist Claude Nicollier, Pilot Scott J. Kelly, Commander Curtis L. Brown, Jr., Mission Specialist Jean-François Clervoy, Mission Specialist John M. Grunsfeld, and Mission Specialist and Payload Commander Steven L. Smith.	2-10
2-7	Detailed schedule of extravehicular activities and SA and FSS positions during SM3A	2-14
2-8	Change-out of Rate Sensor Unit	2-16
2-9	Voltage/Temperature Improvement Kit installation	2-17
2-10	Fine Guidance Sensor change-out	2-19
2-11	S-Band Single Access Transmitter change-out	2-22
2-12	Installation of Solid State recorder	2-23
2-13	New outer blanket layer installation	2-24
2-14	Redeploying the Space Telescope	2-26
3-1	On April 27, 1999, Hubble took pictures of a Martian storm more than 1000 miles (1600 km) across. Left: an image of the polar storm as seen in blue light (410 nm). Upper right: a polar view of the north polar region, showing the location of the storm relative to the classical bright and dark features in this area. Lower right: an enhanced view of the storm processed to bring out additional detail in its spiral cloud structures.	3-2
3-2	The HST WFPC2 captured these images between April 27 and May 6, 1999, when Mars was 54 million miles (87 million kilometers) from Earth. From this distance the telescope could see Martian features as small as 12 miles (19 kilometers) wide.	3-3
3-3	This is the first image of Saturn's ultraviolet aurora taken by the STIS in A bright knot appears in the Supernova 1987A Ring.	3-4
3-4	Saturn viewed in the infrared shows atmospheric clouds and hazes.	3-5
3-5	The crisp resolution of the Telescope reveals various stages of the life cycle of stars in this single view of the giant galactic nebula NGC 3603.	3-6

Figure	Page	
3-6	In this October 1998 image of the Ring Nebula (M57), Hubble looks down a barrel of gas cast off by a dying star thousands of years ago.	3-8
3-7	Hubble sees supersonic exhaust from nebula M2-9, a striking example of a “butterfly” or bipolar planetary nebula.	3-9
3-8	A bright knot appears in the Supernova 1987A Ring.	3-10
3-9	In an observation called the Hubble Deep Field South (HDF-S), the Telescope peered down an 11-billion-light-year-long corridor loaded with thousands of never-before seen galaxies.	3-12
3-10	This HST image provides a detailed look at a “fireworks show” in the center of a collision between two galaxies.	3-13
3-11	Hubble offers an unprecedented close-up view of a turbulent firestorm of starbirth along a nearly edge-on dust disk girdling Centaurus A.	3-14
4-1	Space Telescope Imaging Spectrograph	4-1
4-2	STIS components and detectors	4-3
4-3	STIS spectroscopic modes	4-4
4-4	Multi-Anode Microchannel Plate Array (MAMA) detector	4-5
4-5	Simplified MAMA system	4-6
4-6	STIS filter set	4-8
4-7	STIS specifications	4-8
4-8	Wide Field and Planetary Camera (WFPC) overall configuration	4-11
4-9	WFPC optics design	4-12
4-10	WFPC2 imaging	4-13
4-11	WFPC2 specifications	4-13
4-12	Fine Guidance Sensor (FGS)	4-14
4-13	FGS specifications	4-14
5-1	Hubble Space Telescope – exploded view	5-1
5-2	Hubble Space Telescope axes	5-2
5-3	Design features of Support Systems Module	5-3
5-4	Structural components of Support Systems Module	5-3
5-5	Aperture door and light shield	5-4
5-6	Support Systems Module forward shell	5-4
5-7	Support Systems Module Equipment Section bays and contents	5-5
5-8	Support Systems Module aft shroud and bulkhead	5-6
5-9	High Gain Antenna	5-7
5-10	Data Management Subsystem functional block diagram	5-8
5-11	Advanced computer	5-9
5-12	Data Management Unit configuration	5-10
5-13	Location of Pointing Control Subsystem equipment	5-12
5-14	Reaction Wheel Assembly	5-13
5-15	Electrical Power Subsystem functional block diagram	5-15
5-16	Placement of thermal protection on Support Systems Module	5-17
5-17	Light path for the main Telescope	5-19
5-18	Instrument/sensor field of view	5-20
5-19	Optical Telescope Assembly components	5-21
5-20	Primary mirror assembly	5-21

Figure	Page
5-21 Primary mirror construction	5-22
5-22 Main ring and reaction plate	5-22
5-23 Secondary mirror assembly	5-23
5-24 Focal plane structure	5-24
5-25 Optical Telescope Assembly Equipment Section	5-25
5-26 Cutaway view of Fine Guidance Sensor	5-26
5-27 Optical path of Fine Guidance Sensor	5-26
5-28 Solar Array wing detail	5-28
5-29 Fitting for Solar Array manual deployment	5-28
5-30 Science Instrument Control and Data Handling unit	5-29
5-31 Command flow for Science Instrument Control and Data Handling unit	5-31
5-32 Flow of science data in the Hubble Space Telescope	5-32
5-33 Flight Support System configuration	5-33
5-34 Flight Support System Berthing and Positioning System ring pivoted up with Telescope berthed	5-33
5-35 Orbital Replacement Unit Carrier	5-34
5-36 Portable Foot Restraint	5-35
6-1 “Continuous-zone” celestial viewing	6-4
6-2 HST single-axis maneuvers	6-5
6-3 Sun-avoidance maneuver	6-6
6-4 TDRS-HST contact zones	6-6
7-1 Advanced scientific instruments installed (or to be installed) on HST	7-2
7-2 Systems maintained and upgraded during each servicing mission	7-3
7-3 Processor improvements on HST	7-3
7-4 Data archiving rate improvements	7-3
7-5 Increase in onboard pixels	7-4
7-6 Increase in HST infrared capability	7-4
7-7 Productivity gains on HST with new solar arrays	7-5
7-8 Simultaneous use of HST science instruments	7-5
7-9 Projected medical savings	7-6